

***National Research Council Assessment  
- Prospects for Inertial Fusion Energy***

***Status of the Study  
“An Assessment of the Prospects for Inertial Fusion Energy”***

**Ronald C. Davidson and Gerald L. Kulcinski, Co-Chairs  
Prepared for the 2012 International Symposium on Heavy Ion Fusion  
August 13, 2012**

# A Broad Study – Concepts and Technical Challenges for Inertial Fusion Energy

---

## ▶ **Driver**

- ▶ Lasers, heavy ions, pulsed power, other approaches, --- .
- ▶ Requires high repetition rates and heat handling capabilities.

## ▶ **Ignition**

- ▶ Hot spot versus fast ignition.
- ▶ Indirect versus direct drive.
- ▶ Understand underlying high energy density (HED) physical processes.

## ▶ **Chamber**

- ▶ Tritium handling.
- ▶ Capsule injection and manufacturing.
- ▶ Significant neutron bombardment.
- ▶ Wall materials and design.

## ▶ **Implementation**

- ▶ Environment and safety.
- ▶ Cost competitiveness.
- ▶ Public acceptance.

# Statement of Task (for the Committee)

---

- ▶ **The Committee will prepare a Report that:**
  - ▶ Assesses the prospects for generating power using Inertial Confinement Fusion;
  - ▶ Identifies the scientific and engineering challenges, cost targets, and R&D objectives associated with developing an Inertial Fusion Energy demonstration plant; and
  - ▶ Advises the U.S. Department of Energy on the preparation of an R&D roadmap aimed at developing the conceptual design of an Inertial Fusion Energy (IFE) demonstration plant.
- ▶ **The Committee will also prepare an interim report to inform future year planning by the federal government.**

# Statement of Task (for the Target Panel)

---

## ▶ Target Physics Panel

- ▶ Requires access to classified target physics information.
- ▶ Will inform the Main Committee on the relevant target physics issues.
- ▶ The major task activity for the Target Physics Panel is to:

**“Assess the current performance of various fusion target technologies. Describe the R&D challenges to providing suitable targets on the basis of parameters established and provided by the Committee.”**

# Study Structure

---

## ▶ **Main Committee**

- ▶ Prepare Interim and Final Reports.
- ▶ Twenty-two technical experts from many of the critical science and engineering sub-fields.
- ▶ A twenty-one-month study is envisioned.
- ▶ Provide parameters to the Target Physics Panel.

## ▶ **Target Physics Panel**

- ▶ Seven technical experts in target physics.
- ▶ Panel Chair provides periodic progress reports to the Main Committee.
- ▶ Eighteen-month study.
- ▶ Access to classified information.

# Committee Membership: Acquiring the Right Balance

---

- ▶ **The technical expertise of the committee members covers a broad range of sub-fields:**

- ▶ Plasma physics
- ▶ Fusion physics & engineering
- ▶ Fusion (inertial and magnetic)
- ▶ Radiation physics
- ▶ Materials science & engineering
- ▶ Nuclear engineering
- ▶ Mechanical engineering
- ▶ Laser systems
- ▶ Beam systems
- ▶ Heat transfer
- ▶ Central station power plants
- ▶ Non-proliferation
- ▶ Electric utility industry
- ▶ Economics
- ▶ Energy policy
- ▶ Safety & environment
- ▶ Construction of large-scale energy systems

## Committee Membership

---

**Ronald C. Davidson**, *Co-Chair*, Princeton University

**Gerald L. Kulcinski**, *Co-Chair*, University of Wisconsin, Madison

**Charles Baker**, University of California, San Diego [Retired]

**Roger Bangerter**, E. O. Lawrence Berkeley National Laboratory [Retired]

**Riccardo Betti**, University of Rochester

**Jan Beyea**, Consulting in the Public Interest

**Robert L. Byer**, Stanford University

**Franklin Chang-Diaz**, Ad Astra Rocket Company

**Steven C. Cowley**, United Kingdom Atomic Energy Authority

**Richard L. Garwin**, IBM Thomas J. Watson Research Center

**David Hammer**, Cornell University

**Joseph S. Hezir**, EOP Group, Inc.

**Kathryn McCarthy**, Idaho National Laboratory

**Lawrence T. Papay**, PQR, LLC

**Ken Schultz**, General Atomics [Retired]

**Andrew M. Sessler**, E. O. Lawrence Berkeley National Laboratory

**John Sheffield**, The University of Tennessee, Knoxville

## Committee Membership (Cont.)

---

**Thomas A. Tombrello, Jr**, California Institute of Technology

**Dennis G. Whyte**, Massachusetts Institute of Technology

**Jonathan S. Wurtele**, University of California, Berkeley

**Rosa Yang**, Electric Power Research Institute, Inc.

### Consultant:

**Malcolm McGeoch**, *Consultant*, PLEX, LLC

### National Research Council Staff

**David Lang**, Study Director and Program Officer (BPA)

**James Lancaster**, Director, Board on Physics and Astronomy (BPA)

**James Zucchetto**, Director, Board on Energy and Environmental Systems (BEES)

**Greg Eyring**, Senior Program Officer (DEPS)

**Donald Shapero**, Senior Scholar, Board on Physics and Astronomy (BPA)

**Jonathan Yanger**, Senior Project Assistant (BEES)

**Teri Thorowgood**, Administrative Coordinator (BPA)

---

# Target Panel Membership

---

**John Ahearne**, *Chair*, Sigma Xi

**Robert Dynes**, University of California, San Diego

**Douglas Eardley**, University of California, Santa Barbara

**David Harding**, University of Rochester

**Thomas Melhorne**, Naval Research Laboratory

**Merri Wood-Schultz**, Los Alamos, NM

**George Zimmerman**, Lafayette, CA

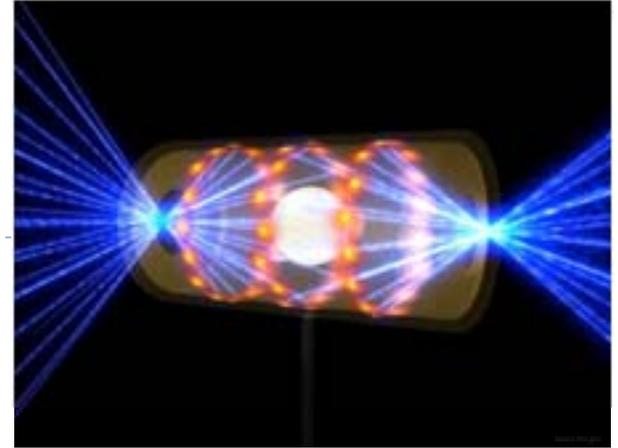
## **National Research Council Staff**

**Sarah Case**, Senior Program Officer\*

**Greg Eyring**, Senior Program Officer

**LaNita Jones**, Administrative Coordinator

\* Until October 2011



# Committee Meetings

---

- **Six full meetings have been completed (more detail in the backup slides)**
  - 1<sup>st</sup> meeting - Washington, DC - December 16-17, 2010
  - 2<sup>nd</sup> meeting - San Ramon, CA - January 29-31, 2011
  - 3<sup>rd</sup> meeting - Albuquerque, NM – March 30-April 1
  - 4<sup>th</sup> meeting – Rochester, NY – June 15-17
  - 5<sup>th</sup> meeting – Washington, DC – October 31-November 2
  - 6<sup>th</sup> meeting – San Diego, CA – February 22-23, 2012

## Other Data-gathering Activities

---

- 1/21/2011. Sent request for 2-pagers on IFE topical areas to all speakers from second committee meeting. 22 excellent, succinct papers received.
- 2/19/2011. Sent expansive list of questions to the second meeting's speakers. 146 pages of detailed, thoughtful responses received.
- Public Comment Sessions at all in-person meetings.
- Documents collected via other external submissions.
- Over 300 submissions received *in toto!*
- All documents received by the committee are available via The National Academies' Public Access Records Office.

# Scope of the Interim Report

---

- ▶ This interim report, which has a *limited scope* and *does not fully address all of the bulleted items in its Statement of Task*, is intended to provide the sponsor with a status report on the committee's progress and a summary of the committee's preliminary conclusions and recommendations based on the information it received during its first four meetings and from its review of relevant previous reports on the subject.
- ▶ Important topics that are not addressed in this interim report—but will be addressed to the extent possible in the final report—include an analysis of the cost-effectiveness of inertial fusion energy, a comparison of the various driver options, and an R&D roadmap at the conceptual level for a national program aimed at the design and construction of an inertial fusion energy demonstration plant, including approximate estimates, where possible, of the funding required at each stage.

# Summary of the Interim Report (i)

---

- **Conclusion 1: The scientific and technological progress in inertial confinement fusion has been substantial during the past decade, particularly in areas pertaining to the achievement and understanding of high-energy-density conditions in the compressed fuel, in numerical simulations of inertial confinement fusion processes, and in exploring several of the critical technologies required for inertial fusion energy applications (e.g., high-repetition-rate lasers and heavy-ion-beam systems, pulsed-power systems, and cryogenic target fabrication techniques).**
- Despite these advances, however, many of the technologies needed for an integrated inertial fusion energy system are still at an early stage of technological maturity. For all approaches to inertial fusion energy examined by the committee (diode-pumped lasers, krypton fluoride lasers, heavy-ion accelerators, pulsed power; indirect drive and direct drive), there remain critical scientific and engineering challenges associated with establishing the technical basis for an inertial fusion energy demonstration plant

## Summary of the Interim Report (ii)

---

- ▶ **Conclusion 2: It would be premature at the present time to choose a particular driver approach as the preferred option for an inertial fusion energy demonstration plant.**
- The committee recognizes, of course, that such a down-selection among options will eventually have to be made. In its final report, the committee will provide examples of key experimental results that will be needed to inform the decision points regarding which driver-target combinations are most likely to succeed.

## Summary of the Interim Report (iii)

---

- ▶ DOE's NNSA supports a major national effort in inertial confinement fusion at the National Ignition Facility (NIF) that is focused primarily on addressing technical issues related to stewardship of the nation's nuclear weapons stockpile and national security.
- ▶ An intense national campaign is underway to achieve ignition conditions on the NIF, and there has been considerable initial technical progress toward this major goal, although progress has been slower than originally anticipated.
- ▶ The current NIF laser, targets, shot repetition rate, production methods, and materials are not specifically designed to be suitable for inertial fusion energy (IFE) applications. Nevertheless, many experiments that could be done using the NIF would be valuable for IFE even if the achievement of ignition is delayed—particularly those that provide experimental validation of predictive capabilities.

# Summary of the Interim Report (iv)

---

- ▶ **Recommendation: Planning should begin for making effective use of the National Ignition Facility as one of the major program elements in an assessment of the feasibility of inertial fusion energy.**

## Timetable for the Remainder of the Study

---

- ▶ Final Report completed by Committee and submitted to DOE Office of Classification for classification review in June 2012.
- ▶ Classification review has been completed and Final Report to enter NRC review process in August 2012.
- ▶ Final Report made available to DOE and public in Fall 2012.

# Detailed Information on the Study

---

# Target Physics Panel Membership: Acquiring the Right Balance

---

- ▶ **The technical expertise on the Target Physics Panel covers the following sub-fields:**
  - ▶ Target physics
  - ▶ Plasma physics
  - ▶ Inertial confinement fusion physics
  - ▶ Materials science & chemical engineering
  - ▶ Computational physics
  - ▶ Analytical calculations

# ICF Target Panel Activities

---

- 5 Meetings: Washington, DC; Livermore, CA; Albuquerque, NM; Rochester, NY; Washington, DC. Agendas available at <http://tinyurl.com/d3ggrv6> .
- The Panel's report has gone through the classification review and NRC review processes. It is now being professionally edited. It will be released alongside the Committee Report.
- An unclassified version of the Panel Report may be included as an Appendix to the Committee Report; a classified annex to the unclassified version will be published separately.

# Committee Meeting 1 – Washington, D.C.

---

- Mike Campbell, Energy Systems Logos Technologies
- Chris Deeney, NNSA
- Harold Forsen, Bechtel, retired
- Robert Goldston, Princeton
- Rulon Linfood
- Ed Synakowski, DOE
- Steve Koonin, DOE
- Bill Brinkman, DOE
- Donald Cook, NNSA
- Steve Fetter, OSTP

## Committee Meeting 2 – San Ramon, CA

---

- Ed Moses, Michael Dunne, Andy Bayramian, Bob Deri, Jeff Latkowski, Tom Anklam, LLNL
- John Perkins, LLNL
- Wayne Meier, LLNL
- Robert McCrory, Stanley Skupsky, Jonathan Zuegel, LLE
- John Sethian, Stephen Obenschain, NRL
- Grant Logan, LBNL
- Michael Cuneo, Mark Herrmann, SNL
- Juan Fernández, LANL
- Dan Goodin, General Atomics
- Stephen Bodner
- Visit to LLNL
  - Ed Moses, Michael Dunne, Tom Anklam, Robin Miles, John Lindl
- Visit to LBNL
  - Paul Alivisatos, Grant Logan, Joe Kwan, Peter Seidl, Alex Friedman, John Barnard

# Committee Meeting 3 – Albuquerque, NM

---

- John Lindl, LLNL
- Chris Deeney, NNSA
- Tom Anklam, LLNL
- Richard Freeman, Ohio State University
- Glen Wurden, LANL
- Irv Lindemuth, University of Nevada at Reno
- Steve Zinkle, ORNL
- Elon Musk, SpaceX, Tesla Motors, & Solar City
- Visit to SNL
  - Steve Rottler, Mike Cuneo, William Styger

# Committee Meeting 4 – Rochester, NY

---

- John Collier, UK Science and Technology Facilities Council
- Hiroshi Azechi, Institute of Laser Engineering, Osaka University
- John Sethian, Naval Research Laboratory
- Philip M. Huyck, Encite, LLC
- Zhang Jie, President, Shanghai Jiao Tong University
- Visit to LLE
  - Robert McCrory, Goncharov, Zuegel, Theobald, Soures, Oliver, Kessler

# Committee Meeting 5 – Washington, D.C.

---

- Boris Sharkov, FAIR GmbH
- Abbas Nikroo, General Atomics
- Dick Meserve, Carnegie Institute for Science
- Brad Merrill, Idaho National Laboratory
- Visit to NRL
  - Stephen Obenschain, Victor Serlin, John Sethian, Yefim Aglitskiy, Max Karasik, Jim Weaver, David Kehne, Steve Terrel, Frank Hegeler, Matt Myers, Matt Wolford

# Committee Meeting 6 – San Diego, CA

---

- Mike Dunne, LLNL
- Jeff Quintenz, NNSA
- Visit to General Atomics target fabrication facilities

## Relevant Previous Studies

---

- ▶ America's Energy Future: Technology and Transformation (BEES, 2009).
- ▶ Review of DOE's Nuclear Energy Research and Development Program (BEES, 2008).
- ▶ Plasma Science: Advancing Knowledge in the National Interest (BPA, 2007).
- ▶ Frontiers of High Energy Density Physics: The X-Games of Contemporary Science (BPA, 2003).
- ▶ An Assessment of DOE's Office of Fusion Energy Sciences Program (BPA, 2001).
- ▶ Review of the Department of Energy's Inertial Confinement Fusion Program: The National Ignition Facility (CPSMA, 1997).